Stress Electrocardiography: A Comparison Of Conventional And Recent Criteria With Angiographic Correlation*

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SUMMARY:

A retrospective study was carried out on 99 patients, who had undergone coronary arteriography to evaluate whether certain new electrocardiographic criteria could effectively enhance the sensitivity, specificity and predictive value of the electrocardiographic stress test over the conventional criteria. The new criteria employed included slow upsloping ST segment depression, exercise induced increase in R-wave amplitude and septal Q-wave phenomenon as against conventional criteria, i.e., horizontal or down sloping ST segment depression.

Sixtyseven patients had a positive test result by the new criteria as against 59 with the standard criteria. The sensitivity increased from 71% to 82% with the recent criteria and in the post-infarction group of 37 patients from 62% to 76%. There was no decrease in the specificity or predictive value. We conclude that the use of new electrocardiographic criteria substantially enhance sensitivity without adversely affecting the specificity, and may be more beneficial in patients with less extensive coronary artery disease.

INTRODUCTION:

Stress electrocardiography has been the most commonly employed noninvasive method for the diagnosis of significant coronary artery disease. The most extensively studied variable of the exercise electrocardiogram is ST segment depression. It has been found to correlate variably with the presence of angiographically demonstrable coronary artery disease (CAD). This can been attributed to various factors for instance mild CAD, ventricular dysfunction, previous myocardial infarction (MI), sub-maximal stress[1], asymptomatic population[2] and a host of other factors.

Several methods have been proposed to improve the diagnostic yield of the exercise ECG test, such as the application of graded and symptom limited exercise tests, the use of multiple lead symptoms or computer quantitated analysis. Much interest however has been focused on the evaluation and usefulness of new electrocardiographic and hemodynamic criteria.

To compare the clinical value of conventional and new electrocardiographic criteria, a retrospective study was carried out on patients who had earlier undergone coronary arteriography. The results were correlated with those of coronary angiography to evaluate whether the recent criteria could effectively enhance the sensitivity, specificity and predictive value of the electrocardiographic stress test.

METHODOLOGY:

1. Patient selection

Nintynine patients referred for evaluation of chest pain or assessment of effort tolerance were studied retrospectively. Patients were excluded on account of the following reasons:

a) MI of less than four weeks duration;

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b) Digitalis therapy at the time or upto a week prior to the test;

c) Clinical evidence of congestive heart failure, cardiomyopathy, valvular disease.

d) ECG evidence of pre-excitation syndrome or bundle branch block;

e) Inability to achieve 75% of the maximal heart rate in the absence of electrocardiographic changes suggestive of myocardial ischaemia.

2. Stress electrocardiography

Stress tests were performed on a multichannel computerized treadmill machine (Model: Quinton 2000). All patients performed graded maximal exercise test in accordance with the Bruce Protocol. The exercise end point was reached when 90% of the predicted maximal heart rate was reached or when one or more of the following criteria were present:

a) Exercise induced ECG changes;

b) Chest discomfort suggestive of angina;

c) Serious dysrhythmias (frequent PVCs in pairs, multifocal PVCs);

d) Severe dyspnoea, fatigue, dizziness or claudication.

Leads monitored during exercise included V4/V5/V6 and / or II/a/VF/V5. Complete 12-lead ECG was recorded at the end of each stage and immediately, two, five and ten minutes in the post exercise period.

Prior to the test a resting ECG was taken and interpreted as being normal or abnormal and with or without pathological Q-waves.

A. ELECTROCARDIOGRAPHIC CRITERIA USED

Two electrocardiographic criteria were used separately, the conventional and recent criteria to compare their diagnostic value in coronary artery disease (CAD).

1. Standard criteria

According to this criterion the test was found to be positive when 1mm or greater horizontal or downsloping ST segment depression was unequivocally present and termed negative when absent. It was termed indeterminate or equivocal when a firm decision could not be made.

2. Recent criteria

a) Appearance of slow upsloping ST segment with 1mm or more ST segment depression 80 m sec after the J-point.

b) R-wave amplitude (in lead V5) estimation at rest and peak exercise. An increase of at least 2mm between rest and peak exercise value was considered significant. It was measured from the PQ junction to the tip of R wave in millimeters[3].

c) The presence of septal Q-waves (small Q waves in V5) at rest and its disappearance and reappearance during exercise and recovery respectively, was taken to be specific for LAD disease[4].

d) Time of occurrence of electrocardiographic changes (stage and/or minutes from commencement of exercise) and total duration of the changes were used as modifiers in deciding whether the test was strongly, moderately and mildly positive.

B. EVALUATION OF HEMODYNAMIC PARAMETERS

The following variables were considered to be significant:

a) Exercise duration of less than seven minutes.

b) Inability to achieve more than 80% of the maximal predicted heart rate.

c) Significant drop or the inability of the SBP to rise at moderate levels of exercise.

d) A rate pressure product of less than 25,000.

e) Development of moderate to severe chest discomfort with or without ischaemic electrocardiographic changes.

f) Occurrence of ventricular arrhythmias which includes PVCs with a frequency of more than 15/min; in pairs, multifocal or short runs of V. Tachycardia.

All the above variables were used as clinical modifiers which when present enhanced the probability that a positive stress test is true and placed the patient in a higher diagnostic category.

C. CARDIAC CATHETERISATION AND CORONARY ARTERIOGRAPHY

All coronary angiograms were performed on Siemens single plane cine-angiographic equipment. Patients had selective coronary angiography by the = udkins technique. Coronary arteries were viewed and filmed in multiple projections, i.e., lateral and right and left anterior oblique views. Coronary arteries with 50% or greater luminal narrowing were considered to have significant stenosis.

The interpretation included as under:

a) Assessment of the degree of stenosis of left main, left anterior descending, left circumflex and right coronary artery.

b) Estimation of left ventricular end-diastolic pressure and left ventricular ejection fraction (Precise measurement of E.F. was not done at the time of catheterization).

D. BIOSTATISTICAL EVALUATION

The stress test results were compared with those of coronary angiography and the sensitivity, specificity and positive predictive value were calculated separately for the conventional and recent criteria. Standard statistical methods were used for the calculation of the above values.

RESULTS:

Out of a total of 99 subjects(97 males), 27 were in the age group 21-40 years and the rest above 40. Thirtyseven had electrocardiographic evidence of transmural myocardial infarction (21 anterior), 14 inferior and 2 both ant. and inf.) ST and T-wave abnormalities were present in 21 and 5 had PVCs at rest. Resting ECG was normal in 41 cases.

1. ELECTROCARDIOGRAPHIC STRESS TESTING

a) ST segment changes on exercise

With the conventional criteria 54 patients were identified to have a positive test. Slow up-sloping ST segment was seen in 7 patients, of these 3 did not have associated horizontal ST depression. This phenomenon was most commonly observed in leads V4-6.

A total of 10 cases developed ST segment elevation (10%). Five had concomitant ST depression in other leads, 9 had a previous MI and 7 reduced LVEF. This phenomenon was equally seen in anterior as well as inferior leads.

b) R-wave amplitude

Twentythree of the 99 subjects fulfilled this criterion. Increase in the R-wave amplitude was the sole positive criterion in only 4 patients. 43% showed a reduced LVEF. Only one patient had normal coronary arteries (3SVD, 7DVD, 12TVD).

c) Septal Q—wave

Five cases demonstrated the septal Q-wave phenomenon and it was present as the only positive criterion in only one patient. All five not only had LAD disease (4 TVD, 1DVD) but four also had a reduced LVEF.

Analysis of the haemodynamic and electrocardiographic parameters on the basis of the results of coronary angiography is given in the Table-1. While evaluating these variables the following observations were considered significant:

i) Fortyfour patients were unable to achieve more than 80% of the predicted heart rate. These patients had an average exercise duration of 6.40 mins. Almost one third had previous MI. 32 (73%) demonstrated ST segment change and a little under half (45%) had evidence of

Table–1

ANALYSIS OF HAEMODYNAMIC AND ELECTROCARDIOGRAPHIC DEPARTMENTS IN DISEASED INDIVIDUALS

	NO. OF PATIENTS	OLD MI	EXER DUR '	MAX BP	PEAK HR	CHEST PAIN	RPP	ST–SEG., CHANGE	R–WAVE AMPLE	SEPTAL Q–WAVE	TIME ONSET	DUR. CHANGE	% HR
SVD	17	8	8.40	185/97	149	7	27,210	10	3	0	5.40	5.50	81
DVD	19	9	6.40	170/98	145	8	25,000	14	7	1	4.33	8.30	78
TVD	41	20	7.30	177/101	149	21	26,480	34	12	4	4.35	7.30	80
TOTAL DISEASED	77	37	7.35	177/99	148	36	26,050	58	22	5	4.40	8.00	79
REDUCED LVEF	37	24	6.40	172/100	149	16	25,930	26	14	4	4.00	8.00	81
NORMAL	22	–	11.00	184/105	171	1	31,890	4	1	–	7.00	6.00	94

diminished left ventricular function. When the results of coronary arteriography were scrutinised 42 (95%) had significant CAD.

ii) The mean value of peak SBP and RPP at peak exercise did not correlate with either the presence or extent of CAD, or with the degree of LV function. Of the 21 patients in whom maximal DBP of 110mm Hg or more was recorded, 71% had demonstrable CAD.

iii) 16 cases recorded ventricular arrhythmias of whom 5 had PVCs at rest and 11 had exercise induced ventricular ectopy. In the former group 3 had significant CAD while 10 patients in the latter had evidence of CAD. Multiform PVCs were recorded in 2 cases and ventricular bigeminy and ventricular tachycardia in each Four of the 11 cases had LV dysfunction.

iv) The exercise test was terminated for one or more of the following reasons:

- Chest discomfort-37, Dyspnoea-10
- Marked ECG change-21
- Ominous arrhythmias-04,
- Fatigue-18
- More than 90% predicted heart rate-2

v) Leads showing ECG changes

a) V4-6 –53 b) V5 alone-3
c) V6 alone-3 d) V1-3-1
e) II, III, aVF –15
f) I, aVL –7

2. STRESS TEST RESULTS

The results of stress tests of all the 99 patients (37 old MI) were evaluated, 67 cases had positive test result by the new criteria as against 59 with the standard criteria. In the post infarction group the new criteria successfully identified 5 patients over and above the conventional criteria.

3. RESULTS OF CORONARY ARTERIOGRAPHY

77 patients had significant (greater than 50% of internal diameter of vessel) CAD. Further breakup of these patients is as follows:

SVD 17 (22%), DVD 19 (25%), TVD 41 (53%). Left main and LAD disease was present in 63 patients and 36 (47%) had moderate to markedly reduced left ventricular function.

4. BIOSTATISTICAL EVALUATION Table-2

Sensitivity, specificity and positive predictive value were calculated for the group of 99, the post infarction group of 37 and a third group without a previous MI. The new criteria enhanced the sensitivity by 10 to 14% in the various groups without any dimunition in specificity or positive predictive value.

Table-2

BIOSTATISTICAL EVALUATION OF TEST RESULTS

	(Total 99)		(Total 87) Post MI		(Total 62)	
	Std.	New	Std.	New	Std.	New
Sensitivity	71%	82%	62%	76%	80%	88%
Specificity	82%	82%	—	—	82%	82%
Positive predictive valid	93%	94%	100%	100%	89%	90%

PS: The data for this study has been collected from the Exercise and Cath. Laboratories of Armed Forces Institute of Cardiology, Rawalpindi.

DISCUSSION:

The primary purpose of this study was to delineate whether the new criteria offered a significant improvement in the sensitivity over the conventional criteria, without adversely affecting the specificity and predictive value. It is apparent from Table-2 that the recent criteria offer an improvement in sensitivity from 71% to 82% in the group as a whole and from 62% to 76% in those with previous MI. This improvement of 10% and 14% respectively does not seem substantial at a glance, but when it is noted that specificity and predictive value are not adversely affected these results may appear quite satisfactory.

The largest comparative study on the diagnostic value of the conventional and new criteria is of Rijneke et al[5], which comprises 623 patients. They recorded an increase in sensitivity of 11% without any decrease in specificity. Murita et al[6] have demonstrated an improvement in sensitivity of 22% (from 55% to 77%) with a negligible decrease in specificity, although they monitored only one lead (CM5). In the recent study by Tellingen et al[7] (total number of patients 122) the sensitivity was enhanced by 20% (31% to 51%) There was a concomitant dimunition in specificity of 18% when slow upsloping ST segment criteria was used, of 39% when only R-wave amplitude was used and only of 7% when both criteria were used. Our result parallel those of Rijneke et al to a great extent although they had a much larger series of patients.

The phenomenon of slow upsloping ST segment was first evaluated by Punsar et al[8]. His semi-quantitative measurements were rather difficult and unreliable. The measurements described by Stuart and Ellested[9] resulted in a better classification and a useful clinical value of the new ST segment criterion. Three of our patients developed slow upsloping ST segment depression without any associated horizontal ST segment depression in other leads. All three had demonstrable CAD. Its presence as the sole positive criterion was relatively uncommon in our study but was as specific as the classical ST segment depression.

Our approach in the analysis of R-wave amplitude was rather conservative. In most studies[1,2,10-17] an increase of or even absence of a reduction of R-wave amplitude (PQ-junction to tip of R-wave) at peak exercise over the resting value is taken as significant. In our study an increase in the R-wave amplitude of at least 2mm over the resting value was considered significant. The reasons for this anomaly were two fold. First, at peak exercise the quality of ECG tracing is often not ideal and the base line (PQ-junction) varies from beat to beat. Second, several studies[11-13] on the evaluation of R-wave amplitude, have demonstrated an increase in the sensitivity at the cost of specificity, when the usual R-wave criteria are employed. In this study, 23 of the 99 patients fulfilled our criteria and there was only one false positive result (specificity 98.5%) of the 23 patients, 4 were those who demonstrated an increase in the R-wave amplitude as the sole positive criterion. All 4 had significant CAD. Suffice it to say that failure of the ischaemic ventricule to decrease its volume during strenuous aerobic exercise has been held responsible for absence of the normal reduction in the R-wave amplitude — Brody effect[18].

The disappearance of the small septal Q-waves at peak exercise and their reappearance on recovery denotes improper septal activation and septal ischaemia and has been shown to be relatively specific for LAD disease on more than

one occasion[4,19,20]. Five of our patients demonstrated this phenomenon. All had extensive CAD and 4 had reduced LV function.

Haemodynamic parameters were helpful only as far as they could distinguish the diseased from the normal and that only to a certain extent. The parameters most useful were, exercise duration, maximum heart rate achieved (and % target heart rate), rate pressure product and time of onset of ECG changes. Unfortunately, non of the variables in our study either electrocardiographic (except septal Q-waves) or haemodynamic alone or in combination could usefully) delineate the extent of the disease (single, double or triple vessel). Nor could we identify a group with reduced LV function. In the latter group the mean peak SBP was 172mm Hg and RPP 25,930. Whereas in those without reduced function these values were 177mm Hg and 26,000 respectively. One of the reasons of failure to demonstrate exercise induced hypotension in patients with a diminished LVEF, was the difficulty in recording blood pressure at peak exercise.

A well known variable, occurrence of chest pain on exercise, although relatively in-sensitive (37%) was found to be highly specific(97%) for ischaemic heart disease.

While analysing data in the sub-group of 37 patients with previous MI, the patients who benefited most from the application of the new criteria were primarily those with inferior wall infarction. These criteria are applicable to only a few cases with anterior MI. Nonetheless, the sensitivity in the group increased from 62% to a respectable 76% 25% of the post MI patients demonstrated ST- segment elevation on exercise. Only one patient with ST-elevation did not have a prior MI.

CONCLUSION:

With the use of new criteria in our study, out of a total of 99 patients, 8 additional cases were diagnosed as positive when compared with conventional criteria. An increase in sensitivity of 10-14% appears significant specially when the specificity and predictive value remain unaffected.

Our study comprised patients who were primarily referred to a specialised cardiovascular institute for evaluation of chest pain. The sensitivity, specificity and predictive value in these patients was reasonably high even when evaluated according to the standard criteia because of the high pre-test disease prevalence (Bayes' theorem). The new criteria would not only be more beneficial in diagnosing patients who have less extensive coronary disease (single and double vessel disease) in whom the incidence of false negative tests is known to be relatively high, but also in correctly identifying false positive ST segment response.

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